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ACCURATE TIME-LINKED DATA ACQUISITION SYSTEM FIELD DEPLOYMENT AND OPERATIONAL EXPERIENCE*†

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ABSTRACT

The Accurate Time-Linked Data Acquisition System (ATLAS) became fully operational on the Long-term Inflow and Structural Test (LIST) turbine at Bushland, Texas in May of 2000. In the LIST configuration, one data acquisition unit is mounted on the rotor and two additional acquisition units are mounted near the base of the turbine. All communication between the rotor unit and the ground is via telemetry. Data acquisition on all three units is synchronized (within +/- 1 microsecond) by slaving the units to universal time with the Sandia-developed Programmable Accurate Time Synchronization Module. A total of 74 channels of instrumentation is monitored by the three acquisition units. Data acquisition occurs at a 30 Hz rate for a continuous data throughput of over 35,000 bits per second, resulting in over 2 GB of ASCII data per day. Implementation of the system is discussed and operational experience is reviewed.

INTRODUCTION

A typical wind turbine data acquisition application, such as that shown in Figure 1, consists of one or more ground-based data acquisition units (GBUs) and at least one rotor-based unit (RBU). Each unit acquires data from sources such as the met tower, the turbine rotor, the turbine nacelle, and the turbine tower. Many different combinations of hardware and software have been used to gather data from wind turbines in the past. However, most of that data is in short segments, typically twenty minutes or less in length, and often the data from the RBU is difficult to accurately time-correlate with the data from the GBU. It has become increasingly obvious in the past few years that, in order to truly understand the critical fatigue loading of wind turbines, researchers need time-series data that is continuous over a period of hours, days, or months[1]. In addition, accurate time correlation between the rotor-based data and the ground-based data is required to enable researchers to determine the impact of turbine inflow on the structural response. Additional information on ATLAS requirements and development may be found in references 2 and 3.

The Accurate Time-Linked Data Acquisition System (ATLAS) has been developed by the Wind Energy Technology Department at Sandia National Laboratories to address these needs by acquiring continuous, long-term, time-synchronized data from multiple GBUs and RBUs for a period of weeks or months. ATLAS consists of both hardware and software components. The major hardware components are data acquisition systems, time-synchronization and communications management units, and, in some applications, telemetry modules. The software consists of the NREL-developed ADAS (Advanced Data Acquisition System)-II data acquisition software (modified to handle continuous data acquisition) and the custom-written ATLAS user-interface, hardware configuration, and programming software[4].

Data Acquisition Subsystem (DAS)

ATLAS utilizes a commercially available data acquisition system known as the KAM-500,‡ which is built and sold by ACRA Control of Dublin, Ireland§. The KAM-500 is a small, rugged, modular, lightweight data acquisition system with a relatively low power consumption that is designed for remote operation in harsh environments. Its operational temperature range is from -40° to +85° C (-40° to +185° F), and it can withstand 100g shock loads.

Data are acquired simultaneously from all channels, and the acquisition time can be precisely specified by an externally supplied synchronization pulse. The data are then formatted into a pulse-code-modulated (PCM)

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‡ Company names and specific product information given throughout this paper are given for information only and do not imply endorsement by SNL

§ ACRA Control Ltd., Landscape House, Landscape Road, Dublin, Ireland.

DISCLAIMER

digital serial stream for transmission over an RS-422 cable, a fiber optic link, or a telemetry link to the host computer. The data are decoded by the receiving computer and placed into computer memory for retrieval and manipulation with software.

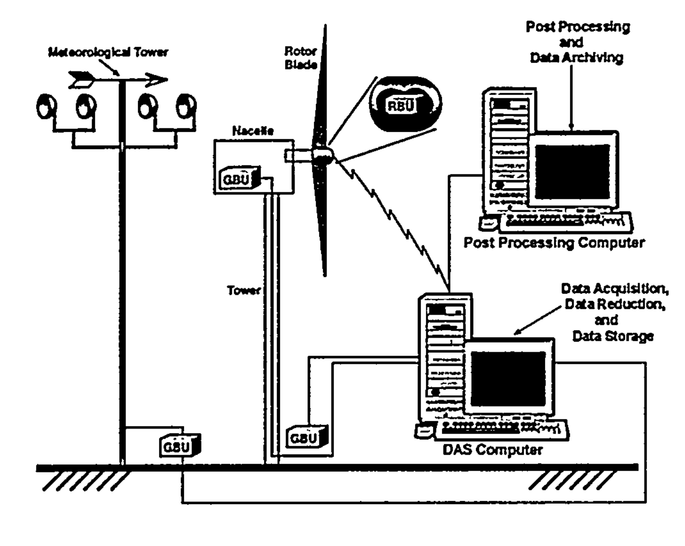

Figure 1. Data Acquisition System Schematic

The KAM-500 is programmable from a remote computer; the data channel selection, data sampling rates, filter cut-off frequencies, channel gains and offsets, bridge excitation voltages, and PCM format are some of the options that can be set with the aid of the ground-based computer. The programming information can be transferred via hard-wire or telemetry from the computer to the DAS at any time.

Time Synchronization and Communications Module

As mentioned in the preceding section, the KAM-500s feature simultaneous acquisition on all channels. The data acquisition timing for each unit may be initiated by an external clock, so the problem of synchronizing data acquisition on all the DAS units becomes one of maintaining synchronous external clocks for the various units. If all units are connected by hard wire, this is not a problem, because we can slave all units to the same clock. However, if there is no hard-wire communication, as may be the case for some installations, synchronization becomes a problem, due to the variable time delay inherent in telemetry. Independent clocks are inadequate because the drift of even a highly accurate, temperature-stabilized clock is on the order of one part per million. This corresponds to an error accumulation of as much as 86 milliseconds (ms) per day per clock, for a difference of up to 172 ms (nearly 1/5 second) per day between two clocks. At sample rates of 10 Hz or higher, two independent systems could be out of synchronization by more than one sample interval at the end of a single day. While this may not be a big problem for some measurements, it is unacceptable for our application.

We have developed the Programmable Time-Accurate Synchronization Module (PATSyM) to maintain time synchronization between DAS units. Each PATSyM utilizes a small, single-card Global Positioning Satellite (GPS) system receiver to re-synchronize its internal 8 MHz clock to universal time (within +/- 1 microsecond) once each second. The internal clock is then used to generate the clock signals that trigger the data acquisition. Data acquired from two independent DAS units, each containing a PATSyM, is time synchronized to within +/- 2 microseconds. The PATSyM also latches the GPS time, accurate to one microsecond, whenever data are acquired. This time is available to the user for inclusion in each data frame as a time-stamp identifier for that frame.

Data Communication Radio Links

Data must be transferred from the rotor- and ground-based units to the ground-based computer concurrent with data acquisition to enable continuous data acquisition over a period of hours, days, or weeks. Although rotor slip rings may be available to effect this transfer from the rotor on some turbines, many of the turbines on which the ATLAS will be used will not have them, and telemetry will be required. Rather than attempt to add the telemetry capability at a later date, we have included it as an integral element of ATLAS.

The rotating turbine blades of a wind turbine create a severe multi-path environment for a telemetry system. ATLAS utilizes low-cost, commercially-available, frequency-hopping, spread-spectrum radio modems, which are resistant to this multi-path interference. The WIT 2400 units from Digital Wireless Corporation** operate in the 2.4 GHz frequency band at data rates up to 115 kbps. 2.4 GHz falls in the ISM (industry, science, and medical) frequency band, and, with a maximum transmit power of 100 mW, may be operated without a license from the Federal Communications Commission (FCC). Up to 16 distinct networks of these modems may operate in the same vicinity without interfering with each other.

** Digital Wireless Corporation, One Meca Way, Norcross, GA 30093-2919.

ATLAS incorporates two pair of these modems; one pair operates in asynchronous mode for programming the RBU and monitoring the GPS receiver status, and a second set operates in synchronous mode for transferring the PCM data from the RBU to the ground.

Prior ATLAS Field Deployment

The first ATLAS prototype was deployed in the field in the summer of 1998 on an Atlantic Orient Corporation (AOC) turbine at the U.S. Department of Agriculture Experiment Station near Bushland, Texas. Success with that system was less than spectacular, due primarily to lightning damage to the instrumentation and to the wind turbine. In June of 1999, we turned our efforts toward implementing ATLAS on the Long-term Inflow and Structural Test (LIST) turbine, also located at Bushland.

Additional information on ATLAS may be found in references 2-6.

LIST PROGRAM APPLICATION

The goal of the LIST program is to acquire long-term, continuous data from a series of wind turbines over a number of years. The current measurement program in Bushland is intended to debug the hardware and software in preparation for future testing of larger scale wind turbines in a variety of wind environments. Figure 2 shows the general layout for the LIST program. The test machine is B, the center one in a row of three Micon 65s. These are fixed-pitch, constant speed, upwind machines. The turbine rotor is instrumented with strain gauges to measure flap and edge bending at the hub and 40% span on each blade, as well as main shaft bending and torque. The tower is instrumented with strain gauges and accelerometers to measure fore-aft and side-to-side bending and acceleration. We also monitor the yaw position, rotor azimuth, rotor speed, and turbine status (on/off). In addition, we monitor the power output from all three turbines, together with extensive meteorological data. Additional information on the LIST instrumentation may be found in reference 1.

The ground-based control and acquisition computer for ATLAS is located in the control building, approximately 59 meters (192 ft) from the base of the test turbine. The ground-based unit, which includes the master DAS and one slave DAS, is located in a small instrumentation building near the base of the turbine, as shown in Figure 2. Data are transferred from the master DAS to the computer via fiber-optic link. User communications with the master unit utilize a second fiber-optic link. The data reception modem for the rotor-based unit (RBU 3) is located inside the instrumentation building, with the antenna mounted on the roof of that building. The distance between the rotor transmitting antenna and the receiving antenna is approximately 25 m (80 ft). User communications with the rotor unit utilize a modem placed inside the control building in a window with a clear view of the turbine. The distance from the rotor unit antenna to the control building antenna is approximately 64 m (209 ft).

The prevailing wind direction is from the southwest, so the rotor is normally oriented to give the communications antenna a clear view of the control building. However, that orientation places the data transmission antenna for the RBU on the opposite side of the tower from the receiving antenna on the instrumentation building. In spite of that, we have a very good radio data link between the RBU and the ground receiving modem.

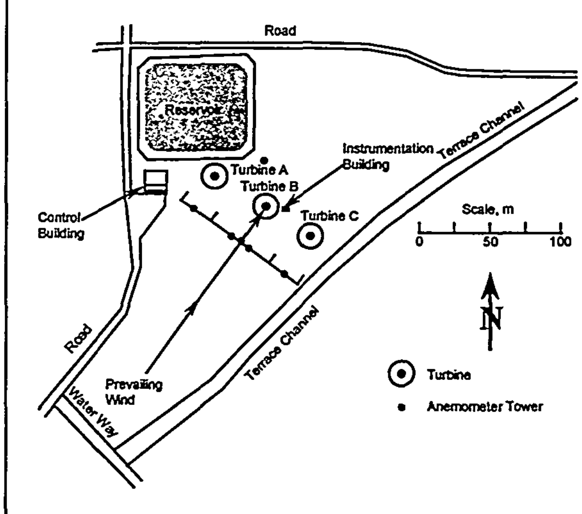

Figure 2. LIST Layout

Rotor-Based Instrumentation

The rotor-based unit for LIST, which we call RBU 3, was designed to acquire 15 channels of strain-gauge data. As shown in Figures 3 and 4, the components are enclosed in a water proof PVC-type container. This container is a design normally used for skin diving and other underwater work and has a sealing lid and a carrying handle. The back of the container has been cut out and replaced with an aluminum plate which serves as a base plate for mounting components. When RBU 3 is mounted to the rotor, this plate is mounted to the metal rotor face so it serves as a heat sink to dissipate the heat generated in RBU 3 during operation. A similar arrangement on the AOC application last year was sufficient to keep the internal temperature of a similar RBU to within 20° F above the ambient temperature. Before we installed the backing plate on that system, the internal temperature stabilized near 160° F, 70° F above ambient.

The three distinct sections of RBU 3 are shown in Figure 3. On the left side are the lightning protection units which provide protection for all externally-connected lines except for the 110 VAC power line. These Citel[††] devices contain both a fast-acting semiconductor diode and a gas tube between the line and ground. The semiconductor diode provides quick response to an electrostatic discharge such as lightning, but it cannot handle much power. The gas tube, on the other hand, does not switch quickly and needs a voltage potential of about 100V to fire, but can handle large amounts of power. The Citel specifications claim a response time of less than 1 nanosecond, with a peak current capability of 10 kA. These units have proven to be quite effective; a number of severe thunder showers occurred at the site this past summer and RBU 3 suffered no detectable damage.

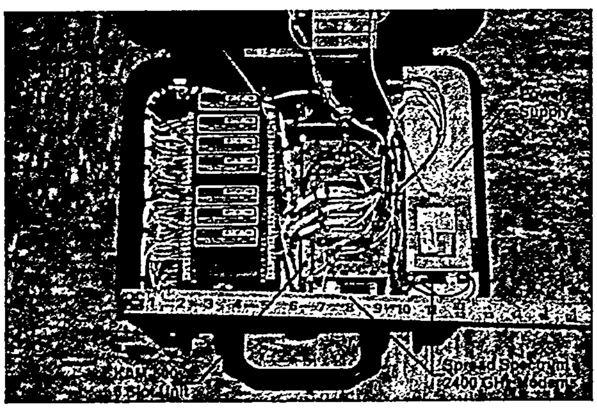

Figure 3. RBU 3 Components

A 6-slot KAM-500 containing three 8-channel, full-bridge strain gauge modules and a single PATSyM module is located in the center of the RBU 3 container. The strain gauge modules are used to acquire 15 channels of strain data from the rotor blades and hub, while the PATSyM module provides the time-synchronization with the ground-based unit and records the time at which each data frame is acquired.

The power supply is located on the right side of the picture. In RBU 3, the power supply is enclosed in its own metal case to shield the KAM-500 and input lines from the electrical noise generated by the 12-VDC switching power supply. The Cosel[‡‡] MMB50-5 power supply generates +/- 12 VDC to power the KAM-500 and the strain gauges. This supply provides good, low-noise power even when subjected to significant fluctuations in input power frequency, wave-form shape and voltage. DC-to-DC convertors powered by this unit generate +8 VDC to power the modems and +5 VDC to power the PATSyM.

RBU 3 also contains two Digital Wireless WIT-2400 frequency hopping modems, as shown in Figure 3, to communicate with the ground. One modem is used to continually transmit PCM data to the ground-based master unit, where it is merged into the single data stream that goes to the ground computer. The other modem provides two-way RS-232 communication between RBU-3 and the ground for monitoring the GPS status and time and for programming the KAM-500 unit.

The GPS antenna receiver unit is mounted on RBU 3 so that the antenna is located on the center of rotation when the unit is mounted on the turbine. This eliminates antenna wobble during turbine operation and results in excellent reception of satellite signals. Initially, we were concerned about the effects of rotation, as the GPS receiver companies we contacted had never heard of an application in which the antenna rotated. We found that rotation is not a major problem below about 150 rpm. Above that speed, the number of satellites that the receiver can find gradually diminishes. At about 350 rpm, the receiver can no longer lock on the required three satellites, and synchronization with universal time is lost. We have not experimented with antenna location to determine how detrimental position wobble is to the signal reception, but we do not anticipate a wobble of several centimeters to have much effect, since the location resolution of the receiver is only +/- 30-50 meters.

110 VAC power is provided to RBU 3 through a rotary transformer mounted on the turbine main shaft. The transformer is powered by an uninterruptable power supply (UPS) mounted on the ground that also provides lightning protection.

All outside connectors such as the strain gauge wires, input power, and the GPS receiver/antenna unit are connected to RBU 3 with circular, weatherproof, mil-spec connectors as shown in Figure 4.

[††] Citel Corporation, 1111 Park Centre Boulevard, Suite 340, Miami, FL 33169

[‡‡] Cosel USA, 1546 Montague Expressway, San Jose, CA 95131

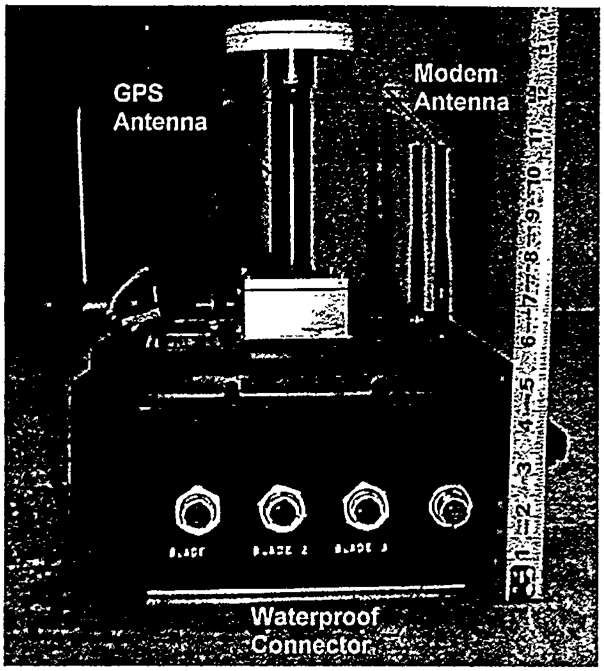

Figure 4. External View of RBU 3

RBU 3 is approximately 33 cm X 33 cm X 14 cm (13in X 13 in X 5.5 in) in size and weighs approximately 65 N (15 lbs).

Figure 5 shows RBU 3 mounted on the rotor of the LIST turbine.

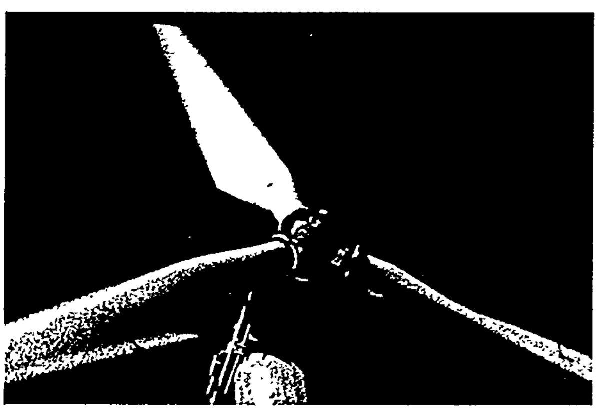
Figure 5. RBU 3 Mounted on LIST Turbine

Ground-Based Instrumentation

The wiring of the ground-based instrumentation avoids potential ground loops and protects the data acquisition systems from lightning. All of the ground-based signals, including the anemometry, tower strain, tower accelerometers, turbine power, and turbine status are carried by twisted, shielded pair cables through underground conduits into the metal instrumentation building. The signal cables are then fed into a large metal instrumentation enclosure, shown in Figure 6. All cable shields are grounded to the metal enclosure, which is tied to the building ground and the site ground. The signal lines are then run through the same Citel lightning protection devices as are used in RBU 3 before they go through signal conditioning (as appropriate) and then connect to the KAM-500 data acquisition systems (the GBU) shown in Figure 7.

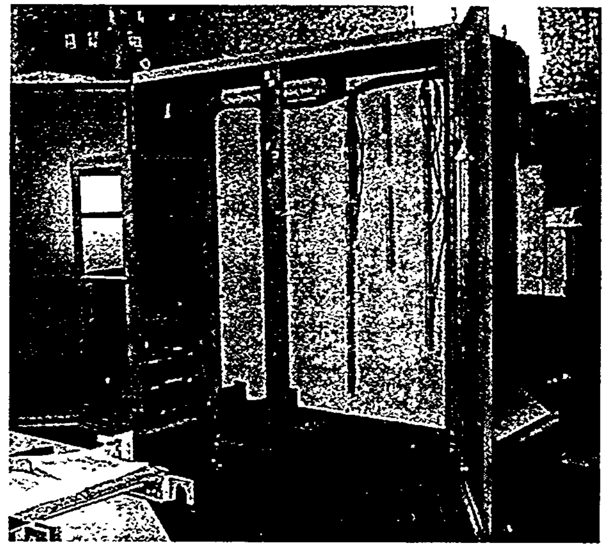
Figure 6. Metal Instrumentation Enclosure

The two KAM-500 6 slot units in the GBU are configured in a master/slave arrangement. The master contains a strain gauge module, a PATSyM module, and two merger/decoder modules. The merger/decoders accept data streams from the slave unit and the RBU and merge those streams with data acquired by the master unit into a single output data stream. One merger/decoder receives the data acquired by RBU 3 via the receiving antenna located on the roof of the instrumentation building. The second one receives data acquired by the slave system in the instrumentation enclosure. The strain gauge module collects the strain and accelerometer data from the tower, while the PATSyM provides the time-synchronization with RBU 3 and captures the time at which each data frame is acquired.

The PATSyM in the master unit also provides the time synchronization for the 6-slot slave unit located immediately adjacent to the master, as seen in Figure 7. This unit contains six, 8-channel analog modules which are used to collect data from 46 analog channels. The PCM output stream of the slave is transmitted via hard wire to the master merger/decoder module.

The RS-422 data stream from the master unit, containing the data from the RBU and the slave unit, is transmitted to the computer in the control building via fiber optic cable and RS-422/fiber optic modems to avoid signal noise and equipment damage due to lightning strikes.

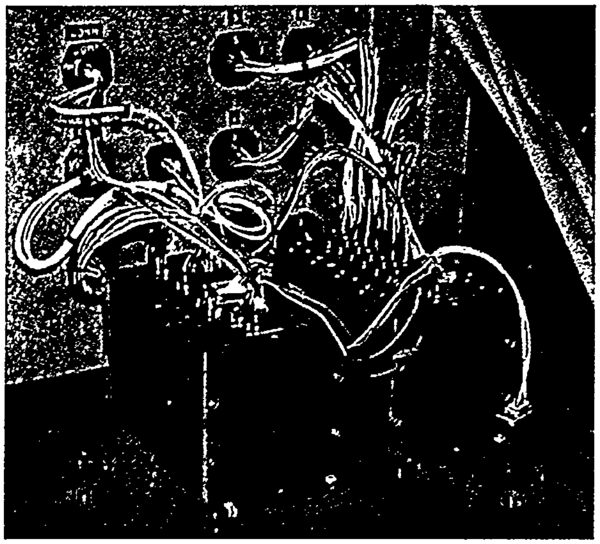

Figure 7. Ground-based Data Acquisition Units in the Instrumentation Enclosure

Data Acquisition and Storage

In the LIST configuration all of the data from the individual units are merged into a single data stream. Each sample of data is transmitted as a single data frame, a 1-dimensional array of 74, 16-bit elements, with each element containing either system information or sampled data as illustrated in Table 1. Of the 74 channels, 59 are turbine data and the other 15 are either time- or hardware-specific information. At our 30 Hz sample rate, 2.6 million data frames, approximately 2.1 GB of ASCII data, are collected daily. Once the data are received and stored in a file on the ground computer, a second computer accesses the file via a local-area network, compresses it, stores the compressed file to another disk, and then deletes the original file. The compressed files are then manually transferred onto a CD for long-term storage or later processing.

OPERATIONAL EXPERIENCE WITH ATLAS

We have been using ATLAS in the field environment for close to two years. While ATLAS has distinct advantages over more conventional systems for acquiring data from distributed hardware, we have experienced some problems with the system.

Accurate Record of Data Acquisition Times

We have found the availability of the universal time to be very useful for debugging, time correlation, and quality assurance purposes. The LIST configuration includes the sample times of both the RBU and the GBU in the data stream. Those times are then used to correlate the RBU data with the appropriate GBU data. We have found that the data in any given frame contains RBU data that are offset from the GBU data by one sample interval – the time delay in telemetering the data from the rotor prevents it from being merged into the correct GBU data frame.

We can also check for the loss of RBU data by examining the sample time intervals in each data file. If we experience a communications failure between the rotor and the ground (RBU data is lost), the RBU data that is merged into the master data stream is not updated – it remains the same until new information is received from the RBU. Thus, if the time increment between two RBU samples is 0, one or more RBU data frames have been lost.

The time-synchronization accuracy resulting from PATSyM is illustrated in Tables 2 and 3. Table 2 shows the actual universal times at which consecutive samples of data were acquired utilizing the internal KAM-500 system clocks (rather than the PATSyM) on the master and on the RBU. The sample rate was set at 30 Hz, so 10 minutes of data should correspond to 18,000 data points. Note that the time interval between most samples is very consistent at 0.033300 seconds for both the master and the RBU. The second roll-over interval (the interval between the last sample in one second and the first sample in the next second) differs from this value. This interval is 0.033337 or 0.033338 seconds for the master (between data points 3 and 4 or 34 and 35) and 0.033294 or 0.033295 seconds for the RBU (between data points 4 and 5 or 34 and 35). The important thing to notice in this table, however, is that the cumulative sample time error is growing as time goes on. Master data point 31 occurs 0.999037 seconds

Frame 1	**Status**	**SyncWord 1**	**Sync Word 2**	**Data Word 1**	**Data Word 2**	**...**	**GPS-Year**	**...**
Frame 2	**Status**	**SyncWord 1**	**Sync Word 2**	**Data Word 1**	**Data Word 2**	**...**	**GPS-Year**	**...**
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Frame N	**Status**	**SyncWord 1**	**Sync Word 2**	**Data Word 1**	**Data Word 2**	**...**	**GPS-Year**	**...**

Table 1. LIST PCM Data Frame Contents

	Master Time		Time Interval		RBU Time		Time Interval
Data Pt	Hr/Min	Sec/Microsec	$T_{i+1}-T_i$		Hr/Min	Sec/Microsec	$T_{i+1}-T_i$
1	15:33	52.900383	0.033300		15:33	52.877283	0.033300
2	15:33	52.933683	0.033300		15:33	52.910583	0.033300
3	15:33	52.966983	0.033337		15:33	52.943883	0.033300
4	15:33	53.000320	0.033300		15:33	52.977183	0.033294
5	15:33	53.033620	0.033300		15:33	53.010477	0.033300
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31	15:33	53.899420	0.033300		15:33	53.876277	0.033300
32	15:33	53.932720	0.033300		15:33	53.909577	0.033300
33	15:33	53.966020	0.033300		15:33	53.942877	0.033300
34	15:33	53.999320	0.033337		15:33	53.986177	0.033294
35	15.34	54.332697	0.033300		15.33	54.019471	0.033300
~~							
18,001	15:43	52.322762	0.033300		15:43	52.307307	0.033300
18,002	15:43	52.356062	0.033300		15:43	52.340607	0.033300
18,003	15:43	52.389362	0.033300		15:43	52.373907	0.033300
18,004	15:43	52.422662	0.033300		15:43	52.407207	0.033300

Table 2. KAM-500 Internal Clock-Driven Data Acquisition Timing

after master data point 1 and master data point 18,001 occurs 9 minutes, 59.422379 seconds after master data point 1. At 30 Hz, data point 31 should occur precisely 1 second after point 1, and point 18,001 should occur precisely 10 minutes after point 1. A similar cumulative error occurs for the RBU. RBU data point 31 occurs 0.998994 seconds after RBU data point 1, and RBU data point 18,001 occurs 9 minutes, 59.430024 seconds after RBU data point 1. For both the master and the RBU, 18,017 data points correspond to approximately 10 minutes of data. Thus, actual data acquisition rate is 30.001 Hz for both acquisition units. Also, note that the times at which RBU data points are acquired are drifting slightly with respect to the times at which the master data points are acquired. Based on the observed drift in this 10-minute file (0.007645 sec), the two clocks will drift one full sample period (0.033300) with respect to each other in approximately 44 minutes. This corresponds to a drift of approximately 33 sample periods in one day and could make time-correlation of the continuous time-series data rather difficult.

Table 3 shows the universal times at which consecutive samples of data were acquired utilizing PATSyMs in both the GBU and the RBU. Note the consistent 0.0333 second time interval between samples, with a slightly longer second roll-over interval. This is due to the re-synchronization of the PATSyM clock to universal time at the start of the second - the sample time interval is not an exact divisor of the KAM-500 8 MHz clock, so we have some extra clock cycles here. In contrast to Table 2, these roll-over intervals are the same for both the master and the RBU – 0.034299 to 0.034301 seconds Note that the RBU data points are offset from the master data points by precisely one time interval, as mentioned earlier. Also note that, for both the master and the RBU, data point 31 occurs precisely 1.0 seconds (within +/- 1 ms) after data point 1, data point 18,0001 occurs precisely 10.0 minutes after data point 1, etc. The time offset between the RBU and the GBU data points remains constant at one sample interval (0.033300 sec). It is obvious that the PATSyM is keeping the two data acquisition units precisely in synchronization.

The second roll-over interval of 0.034300 is longer than the sample interval by 3%. This error may be of some concern when performing operations such as Fourier Transforms on the data. Future software modifications will enable us to add extra individual bits to the data frames and reduce that error to approximately 0.7% for the LIST application and similar or lower values for other applications. This should be small enough to have negligible effect on data analysis operations.

<u>Hardware Problems</u>

Original plans for the LIST data acquisition system envisioned using fiber optics to transmit both the data (the RS-422 link) and communications (the RS-232 link) between the instrumentation building and the control building. Initial attempts to use the fiber optics were unsuccessful, and hard wire was used for both links. For two weeks we experienced exceptional performance in transferring data from the master unit to

Data Pt	Master Time Hr/Min	Master Time Sec/Microsec	Time Interval $T_{i+1}-T_i$		RBU Time Hr/Min	RBU Time Sec/Microsec	Time Interval $T_{i+1}-T_i$
1	13:30	21.998943	0.034299		13:30	21.965242	0.033300
2	13:30	22.032842	0.033300		13:30	21.998542	0.034301
3	13:30	22.066142	0.033300		13:30	22.032843	0.033300
4	13:30	22.099442	0.033300		13:30	22.066143	0.033300
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31	13:30	22.998542	0.034301		13:30	22.965243	0.033300
32	13:30	23.032843	0.033300		13:30	22.998543	0.034299
33	13:30	23.066143	0.033300		13:30	23.032842	0.033300
34	13:30	23.099443	0.033300		13:30	23.066142	0.033300
~~							
18,001	13:40	21.998543	0.034299		13:40	21.965242	0.033300
18,002	13:40	22.032842	0.033300		13:40	21.998542	0.034300
18,003	13:40	22.066142	0.033300		13:40	22.032842	0.033300
18,004	13:40	22.099442	0.033300		13:40	22.06142	0.033300

Table 3. PATSyM-Driven Data Acquisition Timing

the control building – we observed no loss of GBU data frames. However, after approximately two weeks of operation, several thunder showers hit the area and numerous lightning strikes occurred on or near the site. Several hardware communication components in the GBU suffered lightning-related damage, in spite of having lightning protection on the communication lines. At that time we discovered that the turbine ground grid was not tied to the control building ground grid, creating the possibility of a large voltage potential between the GBU and the control building. That may have contributed to the lightning damage. These ground grids have been tied together, the damaged components have been replaced, and the data transmission and communication hard-wire links have been replaced with fiber-optics links. Numerous thunder showers and lightning strikes have occurred in the area since these changes were made, and no further hardware components have been lost due to lightning damage.

Once the lightning-caused damage was repaired, we found that some of the data files created on the ground computer contained duplicate data frames. We eventually traced those extra frames to an error in the PATSyM logic program which introduced an asynchronous clock running in parallel with the normal synchronous clock. Somehow the two clocks occasionally conflicted with each other and resulted in the insertion of an extra data frame in the disk file. Detailed examination of data files created over a period of several weeks following our correction of the logic error confirmed the elimination of this problem.

The radio link for transferring data from RBU 3 to the ground has proven to be quite robust. In a typical 10 minute period, we experience six data frames lost from RBU. Considering the 18,000 data frames acquired during 10 minutes, the RBU radio link to ground loses only 0.04% of the data transferred over it.

During the ATLAS development we experienced numerous failures of the RS-422 data communication chip. This was due to the large static charge build up and associated electrostatic discharges (ESD) that are common in dry areas such as Albuquerque and Bushland (and the California wind farms). The original chips were sensitive to ESD, but that had not been a problem in Ireland and Europe – it became a problem only when they were used in the low humidity of the U.S. southwest. ACRA identified a pin-compatible replacement chip with much greater resistance to ESD, and we have few failures of those components now. ACRA is using the more robust chips on all new systems they produce.

During the development of the ATLAS data acquisition system several different types of DAS modules have failed, the most troublesome one being the strain-gauge module. Although strain gauge data has been successfully acquired from both the AOC and the LIST projects, these modules still continue to fail. Repair of the modules entails shipment to ACRA in Ireland, with a minimum turn-around time of four weeks. The repair time has not been a problem to this point, since we have an adequate supply of spares. According to ACRA, some of the damage is due to ESD, but that doesn't explain all of the damages. Extreme care in handling and programming these modules has reduced the frequency of failure, but has not eliminated it. A thorough check is now routinely performed on each module before it is installed in a data system, and if any suspicious data is spotted, the module is immediately removed and inspected. In addition, a shunt calibration technique to check channel circuit integrity and help detect bad channels on these modules has been developed. This can be performed on any strain-gauge module at any time by remote control.

FUTURE PLANS

The KAM-500 Series 1 DAS units have been used in the development of the ATLAS hardware. During this time Sandia and other companies have served as developmental/test sites for both the hardware and software for ACRA Control. ACRA has now introduced the Series 2 KAM-500, incorporating numerous improvements over the Series 1, based on the experience of their customers. According to ACRA, the Series 2 offers many improvements over the Series 1:

- modified module design to eliminate the ESD sensitivity problem and a completely redesigned strain-gauge module that is much more robust;
- a more powerful power supply to provide excitation for additional strain gauge modules, eliminating the need for an external power supply;
- more user-friendly mainframe design, offering easier access to the instrumentation modules;
- all hardware programming performed via 422 communications;
- additional instrumentation modules;
- true 32-bit software libraries; and
- Windows NT software support

We plan to move to the Series 2 over the next few months, but there are some problems to resolve first. These include:

- modifying the ATLAS and ADAS-II software to work with the Series 2;
- redesigning the PATSyM hardware to fit the Series 2 mainframe; and
- working with ACRA to develop the hardware and software necessary for reprogramming an RBU via telemetry.

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